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Loci of Interference in a Complex Maze[1]

Albert H. Smith
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There have been relatively few studies of interference (retroactive inhibition) with animal subjects. Of eight previous investigations, five yielded a relearning decrement and three, facilitation. With one exception (11) hypotheses have lacked precision and the data and analyses have been coarse, perhaps understandably since the investigators were concerned mainly with demonstrating an over-all interference effect. However, the more numerous transfer experiments with animals, reviewed by Britt (5) and Kogan (11), have raised two general issues relevant to interference which are amenable to study within the framework of the similarity concept, in terms analogous to those which have governed much of the verbal-learning research. The first is the question of the relation between negative transfer and the principles which describe animal maze performance. A few of these principles encompass the influences on the running response of local structural features of the maze, but the majority embody the view that rats form generalizations of the maze pattern which determine the nature of the running response on successive trials. With the exception cited above, attempts to relate these principles to interference have been lacking. The second issue arises from the fact that opinion is almost evenly divided on the question as to whether negative transfer is confined to the loci of changes in the second task of the transfer series (4, 8, 9, 19), or whether it spreads to neighboring unchanged elements (6, 7, 13, 18, 20). It is clear that these questions are related, to the extent that the answer to the first may provide the answer to the other; but from the point of view of method, the second, one might well be investigated independently.

This is an exploratory study with the following aims: (*a*) to produce interference in rat maze learning with acceptable generality, (*b*) to define its relationship to the response patterns identifiable in a complex motor activity, and (*c*) to determine whether or not interference is specific to task components. The three major variables in as many experiments were the similarity factor, temporal point of interpolation, and degree of interpolated practice. The maze design was complex enough to support the expectation that it would elicit such response tendencies as a gradient of elimination of errors (10), anticipatory behavior (16), situationally determined responses (1, 3, 15), and perhaps, as a function of its complexity, some sort of "abstractive" behavior (12). Such complex tasks have sometimes failed to produce interference, and the response patterns therein have typically been difficult to analyze. The ideal of hypothetical specificity clearly demands a simpler task, but this would

[1] This monograph is condensed from a thesis submitted in partial fulfilment of the requirements for the Ph.D. degree at the University of Toronto.

have forestalled the possibility of producing interesting response tendencies associated with the complexity of the task.

I. Method

Subjects

The subjects were 151 albino rats matched in groups of approximately 10—half males, half females to a group. Those of the first two experiments were obtained from a farm colony. Their mean age was 82 days, with a range of 15 days, at the start of preliminary training. Those of the third experiment were bred in the departmental laboratory from animals selected from those of the first experiment. Six litters were allocated to groups by splitting the litters as far as was consistent with matching. Their mean age at the start of preliminary training was 75 days, with a range of three days. Two died and two were discarded for "freezing" during preliminary training in the first experiment. Two were discarded in the original learning session of the second experiment, and one in the same session of the third, for slow running and excessive retracing. The others remained in good health. They were weighed once a week just before feeding. The curves for mean weight gains indicate that a uniform hunger drive was maintained. It was probably stronger in the second and third experiments, since initial weight loss was greater and performance better in terms of errors and running speed. The Chow cubes obtained for these two experiments weighed about 10 per cent less than those used in the first. The percentages of individual weight loss during the first two weeks (O.L. sessions) of these experiments had zero correlation with the individual first-choice error scores.

Apparatus

The maze was an alley-type, 14-unit, multiple-T maze made of half-inch pine, with an open top covered with fine wire screen and painted flat black inside and out. The T-shaped sections were identical with inside dimensions 4 inches square, a 16-inch crosspiece, and a 6-inch stem. The entrance and goal boxes were 10 inches square, 4 inches deep. Drop-type metal doors, eight in all, were placed across the entrance and goal boxes and at the junctions of all units except the first and last two. A straight, 3-foot section of the same alley dimensions was used for preliminary training. It was decided to dispense with the desirable feature of crosspieces at the ends of blinds in order to expedite mastery, hence reduce the total period of food deprivation, and also to facilitate making four changes of pattern daily in the interpolated learning session of Experiment I. The maze rested on the floor of an experimental room separate from the vivarium, and was surrounded by a homogeneously colored screen. The room was illuminated by a 40-watt frosted lamp enclosed by a frosted shade suspended centrally over the maze.

Experimental Design

Five maze patterns were employed in the standard interference paradigm with the following series of correct turns. The O.L. and R.L. task in all experiments was Pattern A, the double alternation scheme, LLRRLLRRLLRRLL. The I.L. tasks in Experiment I were: Pattern B, the mirror image of Pattern A, RRLLRRLLRRLLRR; Pattern C, a modified single alternation scheme, LRLRLRLLRLRLRL; Pattern D, a single-double alternation scheme, LRL-LRLRRLRLLRL; and Pattern E, a

more complex arrangement, RLLRLLR-RLLRLLR. Pattern C was the single interpolated task in Experiments II and III since it produced most interference in Experiment I. The experimental groups are designated by the letters of their respective interpolated patterns, so that "group" and "pattern" are generally interchangeable.

In the O.L. sessions, all animals were given criterion training on Pattern A and were then separated into matched groups on the basis of their first-choice errors. The experimental groups were given the interpolated tasks while the controls were left in their cages but were otherwise treated the same, including feeding. No attempt was made to give the controls equivalent exercise. All then relearned Pattern A to the criterion. The I.L. sessions were as follows: in Experiment I, beginning the day after the last rat finished O.L., the four experimental groups received criterion training on Patterns B, C, D, and E, one group to a pattern. In Experiment II, the three experimental groups, C1, C2, and C3, received criterion training on Pattern C beginning, respectively, on the first, eleventh, and twenty-first day after O.L. In Experiment III, the four experimental groups, C1-C4, received 5, 10, 15, and 20 trials, respectively, on Pattern C, beginning the day after O.L. In Experiment I, each experimental group began R.L. as a group on the day after it finished I.L. Control Group 1 began R.L. with the first experimental group, and Control Group 2 with the last experimental group, to finish I.L. In Experiments II and III, all groups began R.L. on the day after the last rat finished I.L. In Experiment II, one rat failed to reach the criterion of mastery in I.L. and one failed in R.L.

The first experiment represents the major project. The other two were conducted with the hope of confirming an interference effect, in order to obtain comparative data on the effects of interpolated periods of no practice of the magnitude encountered in Experiment I, and to make it possible to specify more exactly the nature of the O.L. task and that of the I.L. task which produced most interference in this experiment. Comparisons among the results of the three experiments should be made in the light of the unexpected fact that the experiments extended over 8, 10, and 5 weeks, respectively. In Experiment II, Group C3 required longer for I.L. than was predicted, and in Experiment III the homebred rats turned in a superior performance.

The I.L. conditions of Experiment I were expected to differentiate the groups in terms of trials to criterion, but there was no basis at this stage for predicting how much. Rather than delay the start of R.L. until the last rat finished I.L. and possibly incur a relearning decrement, it was decided to start each group on R.L. the day after the last rat in the group finished I.L. and to test the alternative procedure in the other experiments. Also, two control groups were used, which began R.L., respectively, with the earliest and latest experimental groups to finish I.L., Groups C and B, respectively. Groups C, D, and E reached the criterion within three days of each other, hence their scores should be compared with those of Control Group 1. Group B required 10 more I.L. trials than Group C, hence its performance is referable to that of Control Group 2. Further reference to the time factor appears in the section on results.

In Experiment II, the delay periods were imposed immediately after O.L. because the use of criterion training made it most convenient to specify them at this stage. Further, the experimental

groups of Experiment I finished I.L. over an interval of 10 days and it was expected that, in Experiment II, the "inactivity" period of at least one of the groups would be about 10 days, thus providing an index of the interference effect of delays of this order. Also, Group C2 in this experiment had an imposed delay of 10 days before beginning I.L. In Experiment III, interpolation directly after O.L. is the most convenient arrangement for imposing variations in the amount of practice. This experiment was also expected to provide an indication of the effects of imposing different periods of "inactivity" between the end of I.L. and the beginning of R.L.

Previous research provided few criteria for selecting from the very large number of patterns of turns possible with this maze those likely to produce marked interference. The I.L. tasks must be similar to the O.L. task and at least three degrees of similarity are required. A maze with identical reversible sections permits such variations without changing the serial positions of the units. The linear maze comes closest to producing an uncomplicated goal gradient when this is the primary interest. In most of the present patterns the line of progress is roughly linear and the series of turns, including numbers and positions of reversals, are the same in the first and second halves. The double alternation task, Pattern A, was chosen arbitrarily for O.L. In terms of number of reversals, its mirror image, Pattern B, is maximally dissimilar with 14; but if rats can generalize complex response patterns, this task could be expected to become functionally more like Pattern A. Patterns D and E, with eight and four reversals, respectively, represent increasing degrees of similarity to Pattern A. It also seemed desirable to interpolate a less difficult task, a single alternation pattern. However, the experimental room was too small to accommodate 14 single alternations, so two left turns were inserted at its mid-point to yield Pattern C. This, also, has 8 reversals compared to Pattern A.

Training Procedure

All training began at 5:30 P.M. and was at the rate of one trial a day. Preliminary training consisted of five trials in the straight runway. The running order in all series except the I.L. session of Experiment I was half of the males, half of the females, which was repeated, always in the same individual order. In the I.L. session of Experiment I, the rats were run by groups in the order, B, C, D, and E, males first within groups. At the end of runs, the rats were permitted to nibble the food in the goal box for a few seconds and were then fed three-grain poultry wheat for 30 minutes in separate feeding cages in the vivarium. Males consumed on the average nine grams, females eight. After this, each rat received a cube of Fox Chow (6-7½ grams) which was completely consumed. Greens were given once a week instead of Chow. The minimum period of food deprivation was 22 hours. The performance indices were: (*a*) first-choice errors, in which the rat placed at least both feet in the blind when at a choice point for the first time in the run; (*b*) retrace errors, defined as retracing any segment of the true path or a blind, each unit being regarded for this purpose as having two segments to the crosspiece and one to the stem; (*c*) seconds per run; and (*d*) number of trials to reach the criterion. Running time per unit was not recorded. A fairly stringent criterion of three successive errorless runs (absence of first-choice errors) was imposed in order to set up stable habits.

II. Results

Ancillary Data

Performance curves. First-choice errors in all sessions exhibited smooth, negatively accelerated curves in contrast with the irregular curves for time scores, and especially for retracing. This is a common finding which may be interpreted as supporting the view that first-choice errors measure primarily "cognitive" functions, whereas the other indices reflect motivational and disruptive processes.

Matching. The groups were matched on the basis of first-choice errors in O.L. to yield almost identical group means in each experiment. Concurrently, close matching of mean numbers of trials and mean running speed per group were also achieved. In terms of t ratios and F ratios, none of the intergroup differences for any performance index in the O.L. sessions of the three experiments was statistically significant. The largest t ratio was .75, and most of them were close to zero. These data have been omitted from most of the subsequent tabulations.

Maze reliability. The product-moment correlations between the first-choice errors in the odd and even trials of the first 20 trials of Experiments I and II and the first eight O.L. trials of Experiment III were $.83 \pm .006$, $.95 \pm .016$, and $.74 \pm .006$, respectively. Split-half coefficients for these trials were $.82 \pm .006$, $.69 \pm .009$, and $.73 \pm .006$, respectively. All coefficients were corrected for attenuation by the Spearman-Brown formula.

Sex differences. Each group was equated for sex and the comparisons were based on mean group scores. The variance in first-choice errors due to sex was not large enough to warrant removing it from the residual term in testing for significance, since the F ratios for interference based on the pooled data were much larger than required for significance. Aside from control, however, the small but significant female superiority evident in these data is opposed to previous findings of small but significant differences favoring males. This is probably the result of greater drive since, by intention, the females received from 10 to 15 per cent less Chow than the males (smaller cubes), which may have been disproportionate to need.

The time factor. The imposition of criterion training gave rise to a problem of control of the time factor in the I.L. sessions. It was assumed to be optimal for negative transfer that stable habits of about equal strength be established in the O.L. and I.L. sessions. The following outcomes are relevant. (*a*) All groups were closely matched in terms of mean number of trials in the O.L. sessions. (*b*) In the R.L. session of Experiment I, the mean difference in first-choice errors between the two control groups was statistically insignificant (Table 2). (*c*) In Experiment II, the mean differences in interference between Groups C1 and C2, and between Groups C2 and C3, representing, respectively, zero and 10, 10 and 20, days' delay between O.L. and I.L., were insignificant whereas the difference between Groups C1 and C3 was significant at the one per cent level. Hence the chances are borderline that 15 days without practice between O.L. and I.L. would significantly affect interference (Table 4). (*d*) In Experiment III, none of the intergroup mean differences in interference, taking the experimental groups in pairs, was statistically significant. Here, up to 15 days' delay prior to R.L. did not appreciably affect interference (Table 4).

TABLE 1
PER CENT RETENTION AND PER CENT INTERFERENCE
($N=10$)*

Experiment	Group	Per Cent Retention			Per Cent Interference		
		First-choice errors	Trials	Times (secs.)	First-choice errors	Trials	Times (secs.)
I	B	82.2	50.7	67.7	−2.4†	−14.7†	−9.9†
	C	58.5	31.6	52.6	30.9	34.9	22.1
	D	71.8	36.4	63.5	15.2	24.9	5.9
	E	71.0	34.7	61.9	16.2	28.5	8.3
	Con. 1	84.7	48.5	67.5			
	Con. 2	80.2	44.2	61.6			
II	C1	55.9	37.9	51.0	26.4	23.6	17.7
	C2	59.8	35.0	56.7	21.2	29.4	8.7
	C3	67.1	44.4	56.4	11.6	10.5	9.2
	Con.	75.9	49.6	62.1			
III	C1	68.4	46.4	70.2	22.6	−5.5†	3.4
	C2	63.8	37.0	68.3	27.8	15.9	6.1
	C3	64.0	38.5	68.9	27.6	12.5	5.2
	C4	57.0	31.5	60.7	35.5	28.6	16.6
	Con.	88.4	44.0	72.7			

* Groups B and E, Experiment I, had 9 rats each; Groups C1, C2, and the controls, Experiment III had 11 each.
† A minus sign indicates facilitation.

Over-all Retention and Interference

The group results were treated by the *savings method* (Table 1). Retrace errors have been omitted from this table because of their great variability and the small amount of interference they revealed. In the first experiment the O.L. task was retained best by the controls, then by the experimental groups in the order, B, D, E, and C. Marked interference occurred for Groups C, D, and E, in comparison with the controls, and this was greatest for Group C on every index. The interpolation of Pattern B facilitated the relearning of Pattern A. The data for Experiments II and III, in which Pattern C was the only interpolated task, also reflect marked interference. In Experiment II, interference tended to decrease with increase in temporal separation of the I.L. and O.L. tasks. In Experiment III, it tended to increase with increase in number of I.L. trials. The maximum group interference in these experiments, in terms of first-choice errors, was 35.5 per cent, the mean for the ten experimental groups, 23.5 per cent. Such results clearly depend on specific experimental conditions and the present ones may not have been optimal. However, they produced a much smaller amount of interference than that typically shown by human subjects in verbal tasks.

The relative positions of the group mean first-choice error curves (Fig. 1) indicate that there was net positive transfer during I.L., and to a lesser extent during R.L., except for Group C. This is most marked for Group B. The control group curves are similar in form and about the same distance apart. The R.L. curves for the controls are closer to the abscissa than the other R.L. curves, except that of Group B. The relative positions of the I.L. and R.L.

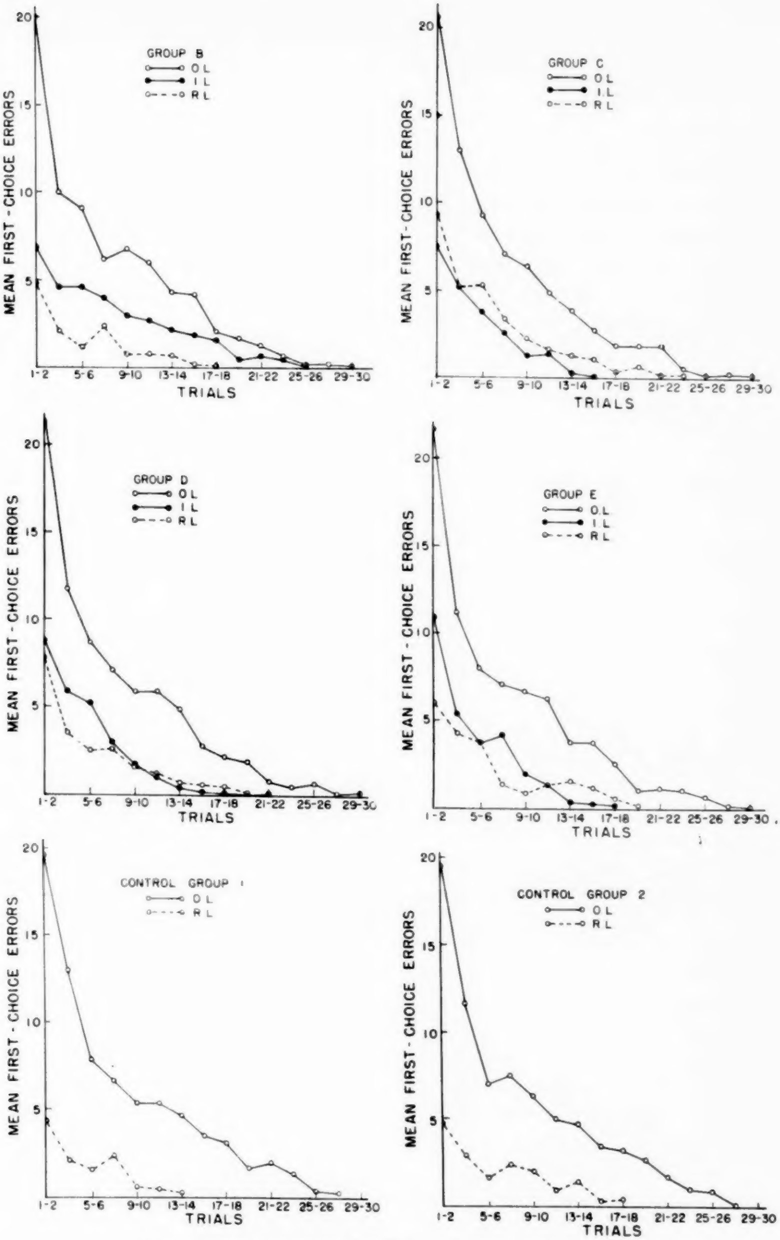

FIG. 1. Mean first-choice errors for successive pairs of trials.

curves for Group C are opposite to those of the corresponding curves for the other experimental groups, indicating net negative transfer from I.L. to R.L. in this case. The fact that Groups D and E made more errors than Group B in the earlier trials of the I.L. and R.L. sessions indicates that there was either less positive transfer or more negative transfer in these two cases. Disruption during I.L. was not directly related to number of reversals during I.L. The group mean errors for the I.L. sessions were: Group B, 14 reversals, 36.2; Group D, 8 reversals, 26.4; Group E, 4 reversals, 28.8; and Group C, 8 reversals, 22.2. Nor was interference during R.L. directly related to number of reversals. Group B, with most errors during I.L., averaged 13.0 in R.L. and Group C, with fewest during I.L., averaged 31.1 in R.L. Groups D and E averaged 21.1 and 21.9 errors respectively, Control Groups 1 and 2, 11.8 and 16.6, respectively. This point is elaborated in Section III.

There were no controls for the I.L. sessions, but the nature of the disruption due to the presence of reversals may be assessed indirectly from the comparisons with Pattern B (Table 2) in which all choice points were reversed. The t ratios are significant in seven of twelve comparisons, and in the other five are larger than the corresponding ratios for the O.L. session (not shown). The F ratios (Table 3) are generally larger than the t ratios, variance between groups being significant on all indices. Variance within groups did not change significantly as a result of interpolation. The differences between animals (rows) were not significant at the end of the I.L. session and were less than in the O.L. session.

The relearning comparisons involving Group B, other than those with the controls (Table 2), are not relevant to interference, but they indicate the change

TABLE 2

SIGNIFICANCE OF GROUP DIFFERENCES IN TERMS OF t RATIOS: EXPERIMENT I

Groups	First-choice errors	Retrace errors	Trials	Times (secs.)
	I.L. Session			
B-C	3.27**	2.31*	4.68**	3.18*
B-D	2.28*	2.08	3.99**	1.45
B-E	2.01	1.48	3.74**	1.59
C-D	1.59	.03	.65	1.14
C-E	1.91	1.08	1.47	.96
D-E	.72	.94	.70	.21
	R.L. Session			
B-C	3.77**	.63	1.74	2.29*
B-D	2.64*	.64	1.71	.67
B-E	2.37*	.09	2.19*	.84
B-Control 2	.91	.11	.73	.71
C-D	2.17*	.82	.34	1.97
C-E	1.77	.60	.09	1.56
C-Control 1	3.92**	.61	2.01	2.20
D-E	.22	.73	.53	.41
D-Control 1	3.05**	.59	2.07	.56
E-Control 1	2.69*	.04	2.41*	.88
Controls 1 and 2	1.24	.08	.96	.63

* Significant at the 5% level.
** Significant at the 1% level.

TABLE 3

SUMMARY OF F RATIOS: EXPERIMENT I

Source	First-choice errors	Retrace errors	Trials	Times
	O.L. Session			
B.G.	.12	.06	.14	.03
W.G.	1.20	1.34	1.00	1.49
B.R.	2.18*	3.05**	.99	3.96**
	I.L. Session			
B.G.	5.17**	2.56**	12.17**	5.87**
W.G.	1.73	.85	1.16	1.05
B.R.	1.99	.40	1.63	1.22
	R.L. Session			
B.G.	7.10**	.32	2.46*	1.55
W.G.	1.13	.94	1.19	1.11
B.R.	1.79	.66	2.13*	2.16

* Significant at the 5% level.
** Significant at the 1% level.

from I.L. to R.L. in the distribution and magnitudes of the significant t ratios among the performance measures. In the R.L. session, trials did not generally differentiate the groups in terms of t ratios and the F ratio for this index is much smaller. Retrace errors did not differentiate the groups. This kind of error decreased markedly during relearning; within the groups its mean varied greatly from trial to trial and the total group mean differences were small. First-choice errors provided the only useful index of interference for experimental-control group comparisons. The variance between groups on this index increased from I.L. to the end of R.L. For these reasons, only first-choice errors were employed in the subsequent analyses of the effects in the separate units.

In Experiment II, interference was significant in two of the comparisons with the controls but in the case of only one of the other group differences, C1-C3 (Table 4). Interference then, decreased as the temporal interval between O.L. and I.L. increased, but it required from 10 to 20 days of practice to differentiate the experimental groups significantly. The F ratios were not computed for these data.

TABLE 4

SIGNIFICANCE OF GROUP DIFFERENCES IN FIRST-CHOICE ERRORS IN THE R.L. SESSIONS: EXPERIMENTS II AND III

Groups	t ratios	
	Exp. II	Exp. III
C1-C2	1.00	.10
C1-C3	2.95**	.76
C1-C4	—	.96
C1-Control	3.92**	5.81**
C2-C3	1.04	.82
C2-C4	—	1.00
C2-Control	2.94**	7.19**
C3-C4	—	.39
C3-Control	1.87	7.00**
C4-Control	—	5.57**

** Significant at the 1% level.

All four groups in Experiment III made significantly more errors during R.L. than the controls (Table 4). While interference tended to increase to a maximum with increase in amount of interpolated practice, then decreased with further practice, none of the mean differences between the experimental groups was statistically significant.

Analysis of the Response Pattern

The O.L. curves (Fig. 2) show the typical pattern of unit errors made by these groups. The curves reflect a tendency to backward elimination of errors partly obscured by a marked tendency to enter the last goal-pointing blind in Unit 12 and an uptilt in the curve toward the goal due to relatively more entrances to the blinds in Units 10, 11, 13, and 14. These trends are reflected in a convex serial position curve of errors which is the reverse of that commonly found in serial verbal learning, probably due to the fact that errors of anticipation and perseveration in this maze could produce correct responses, especially in the units near the center. In general, errors were relatively more numerous in the even-numbered units and relatively fewer in the odd-numbered ones, in Units 4 to 14, inclusive. The fact, however, that this trend was disturbed between Units 2 and 4 (3 and 5 in the case of Pattern D), suggests that there were opposing response tendencies in this area. Incidentally, this feature does not appear in the corresponding curves for retrace errors (not shown); all of them exhibit the regular alternating pattern throughout.

A further analysis of the O.L. response pattern showed that: (*a*) there was no preference for either side of the maze,

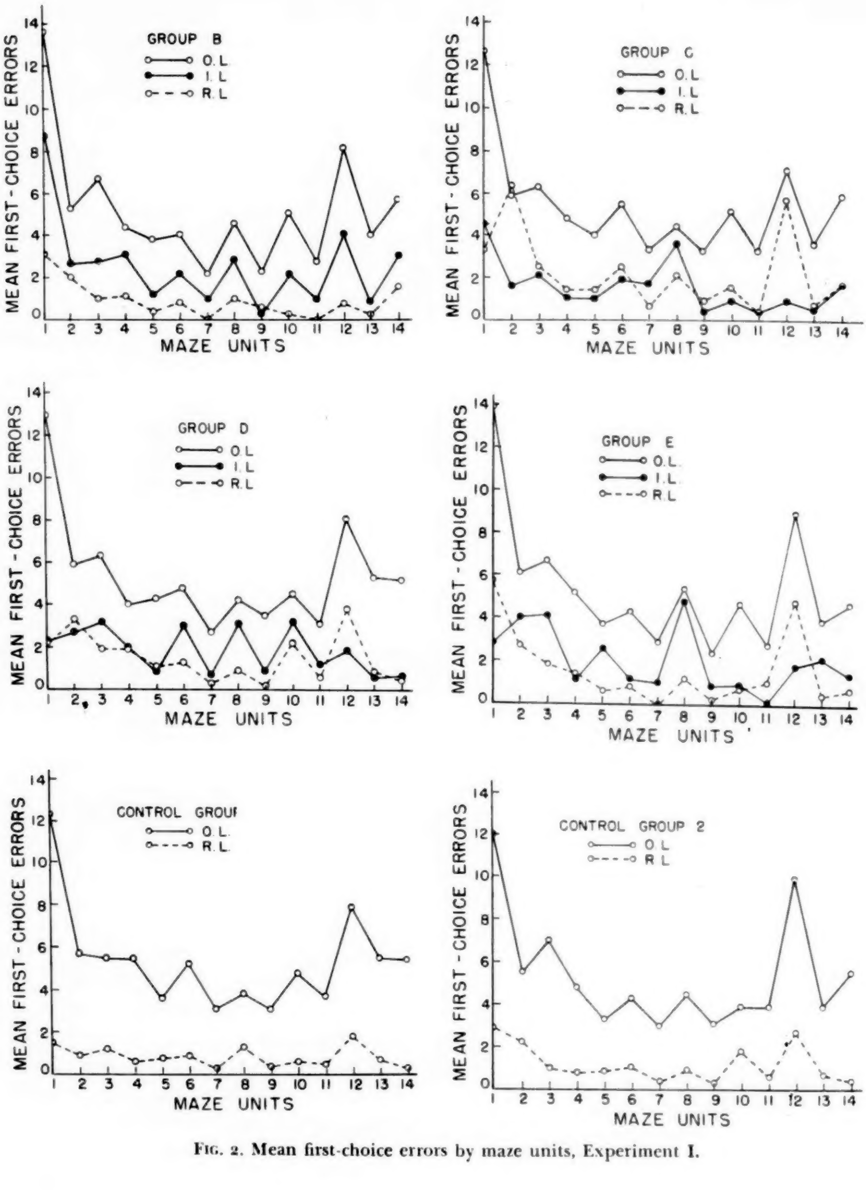

Fig. 2. Mean first-choice errors by maze units, Experiment I.

disregarding errors in Units 1 and 12; (*b*) disregarding the errors in Units 1, 2, 12, and 14, fewest entrances were made into blinds pointing backward, i.e., away from the food box at a 90-degree angle with it; (*c*) disregarding Unit 12, the blinds in Units 6, 10, and 14, pointing directly away from the food box, were entered about as frequently as the other even-numbered blinds; (*d*) there was no appreciable indication of handedness in the data. The most marked response tendency was the alternating pattern of errors jointly constituted by the responses described in (*b*) and (*c*).

The effects of interpolation on the original pattern of errors could not have been predicted from the number and serial positions of the reversals. These changes did not result in a generally different response pattern, but any subsequent disruption of behavior radical enough to reverse the direction of the error curve tended to occur near the start of the maze and to a lesser extent near the goal. The pattern of errors in the other units was quite stable, even when the absolute numbers of errors in specific units varied greatly from one pattern to another and from O.L. to I.L. for a given pattern.

In more detail, the I.L. curve for Pattern B, with all units reversed, is generally similar in form to the O.L. curve for Pattern A, except that the curve changes direction between Units 2 and 3, instead of 3 and 4. The I.L. curve for Pattern C, with reversals in Units 2, 3, 6, 7, 8, 9, 12, and 13, differs only slightly from that for Pattern A, namely, in the number of errors in Unit 4 relative to Unit 5. The reversals in Pattern D were at the ends of the maze in Units 2 to 5, inclusive, and in Units 10 to 13, inclusive, but the disturbance of pattern was near the start. The I.L. curve for Pattern E, with reversals in Units 1, 3, 12, and 14, changes direction relative to the O.L. curve between Units 1 and 2, 5 and 6, and 13 and 14. Here, a reversal in Unit 1 did not produce maximum errors in Unit 1 but in Unit 2, whereas in the curve for Pattern D the same thing occurred although Unit 1 was not reversed during I.L. In the Pattern B curve, a reversal in Unit I did not produce a change in the frequency of errors in this Unit. There were no reversals in Units 6 to 9, inclusive, of Patterns D and E, but the frequencies of errors differ markedly in these Units in the two patterns, although the general forms of the curves are similar.

In the absence of controls for the I.L. session, the statistical significance of the above changes can be assessed only indirectly by reference to Pattern B. As one of a number of analyses, the *t* ratios were computed for the differences in first-choice errors in each maze unit between the experimental groups taken by pairs, the purpose being to provide a comparison of the pattern of significant disruption during I.L. with that of interference during R.L. None of the corresponding differences between the O.L. group scores in each unit, taking the groups two at a time, was significant. In the I.L. data, there were significant differences in 16 of 42 unit-pair comparisons involving Pattern B. But significant differences failed to appear in 11 of 22 comparisons with Pattern B in which only one of the choice points in the patterns being compared was reversed during I.L., and they did appear in scores in 5 of 10 units in which both choice points in the two patterns being compared had been reversed. Together with the foregoing description of the O.L. and I.L. curves, these data indicate in a general way the extent of disruption

due to interpolated reversals and the limits of specificity of the effects of reversals on disruption.

The R.L. curves should be read with the *t* ratios for the mean group differences between the experimental and control group scores in each maze unit (Table 5). The positions of the interpolated reversals are indicated by lines under the *t* ratios for the units affected. Interference occurred mainly at or near the start of the maze in Units 1 and 2, and also in Unit 12. These units accounted for seven of twelve significant differences, Units 4, 6, and 14 for the other three. Despite the diverse patterns of interpolated reversals, the forms of the R.L. curves are very similar to that for Pattern A. Greater dispersion of the errors indicative of interference would have been expected if the effects of reversals had been specific to their loci during I.L. The only marked departures in the experimental group curves from the corresponding points in the O.L. curves are (*a*) a shift of the point or points of reversal of direction of the alternating error curve (B,C, D, and E), and (*b*) displacement of the unit of maximal error frequency near the start of the response pattern from Unit 1 to Unit 2 (C and D). However, changes similar to (*a*) occurred in the curves for the control groups, which had had no I.L.

As for positions of reversals, in Pattern B, with all choice points reversed during I.L., the rats continued to make errors maximally in Unit 1 during R.L. In this case, however, all the unit-score differences are insignificant except that for Unit 12, which is significant for facilitation. In Pattern C, Unit 1 was not reversed during I.L. but Unit 2 was; here, however, relatively more errors were made in Unit 2 than in Unit 1 during R.L., and significant interference also

TABLE 5

Significance of Differences in First-Choice Errors by Maze Units Between Experimental and Control Groups: Experiment I, R.L. Session

Group Pair	Maze Unit 1	2	3	4	5	6	7	8	9	10	11	12	13	14
B-Control 2	**.08**	**.26**	**.00**	**.29**	**.54**	**.19**	**1.82**	**.11**	**.33**	**1.57**	**.91**	**4.32****	**.34**	**1.75**
C-Control 1	2.37*	**4.70****	**.32**	1.04	.95	**3.20****	**.28**	**1.18**	**.47**	1.15	.37	**4.38****	**.00**	2.26*
D-Control 1	1.10	**2.76***	**1.06**	**2.21***	**1.27**	.68	.00	.40	.20	**1.63**	**.13**	**1.72**	**.20**	.26
E-Control 1	**3.65****	1.00	**1.05**	1.23	.29	.21	2.00	.26	.23	.10	.52	**3.60****	.27	**.65**
Controls 1 and 2	1.24	1.16	.35	.34	.18	.17	.84	.73	.14	1.17	.37	1.20	.00	.15

Note.—Boldface indicates a reversal during I.L.
* Significant at the 5% level.
** Significant at the 1% level.

occurred in Units 6, 12, and 14, all reversed. In Pattern D, there was a similar effect to that for Pattern C in Units 1 and 2, but with relatively fewer errors in Unit 2, and a significant amount of interference also occurred in Unit 4 (reversed). In Pattern E, with a reversal in Unit 1 during I.L., there was an effect during R.L. similar to that in the case of Pattern B. In the three patterns that produced interference, therefore, when interpolated reversals came in Unit 2, they were accompanied by maximal interference in Unit 2 rather than Unit 1. Reversals in Unit 12 were also followed by interference (except for Pattern B) which was significant in the cases of Patterns C and E, but not by a change in the direction of the curve. This may have been due, of course, to the fact that Unit 12 was a major source of errors in all sessions.

Except in the case of Unit 6, Pattern C, and Unit 4, Pattern D, interpolated reversals in units other than the first two and No. 12 were not accompanied by a significant number of errors indicative of interference nor changes in the direction of the curve during R.L.

The patterns of t ratios for the differences between the unit scores for I.L. and R.L. were also compared, taking the four experimental groups two at a time. This analysis is obviously of no relevance to absolute interference since the controls were not involved. However, it brought out clearly the lack of correspondence between the pattern of response disruption during I.L. and that indicative of interference in R.L. There were 30 significant t ratios in the I.L. comparisons, twice as many as in the R.L. comparisons, but only for three units were they common to both sessions, namely, two group-pair comparisons for Unit 2, one for Unit 10, and one for Unit 12.

Interference tended to occur at loci of reversals rather than loci of nonreversals—there were seven and two significant t ratios, respectively—but it failed to occur significantly at 13 loci of reversals, excluding the 14 in Pattern B. Reversals tended to produce relatively more interference when they were the first of a series. This occurred in Pattern C, Units 2, 6, 12; in Pattern D, Unit 2; and in Pattern E, Units 1 and 12, in the last case a series of two reversals interrupted by a nonreversal. Spread of the interference effect of reversals is also indicated by the fact that nonreversals immediately adjacent to reversals tended to result in greater score differences between the experimental animals and the controls than at other choice points, although not generally in terms of statistical significance. This happened in Pattern C, Units 1, 4, 5, 10, and 14; in Pattern D, Units 1 and 6; and in Pattern E, Units 4 and 11. The exceptions to this trend are: Pattern C, Unit 11; Pattern D, Units 9 and 14; and Pattern E, Unit 13.

The total error curve by maze units for Trials 1 and 2, and the means for the first two pairs of trials, the first three pairs, etc., to and including Trials 1 through 12 were plotted for the O.L. session; the total errors for Trials 1 and 2 and the means of the first six pairs of trials only were plotted for the other two sessions because of excessive fluctuations in the curves for these sessions. These curves are not shown here. This analysis revealed that the response pattern was clearly identifiable in the early series of trials and changed little as practice proceeded. The curve tended to be flat for the initial pair of trials and the bowing became progressively more marked with practice.

There are two further points of note.

First, the total errors in Unit 1 was 108 for the first two trials; the average of the first two pairs was 106, and of the first three pairs, 134. After this the means decreased consistently. This did not happen for any other unit; in all of them the means decreased from the start as the total errors for successive pairs of trials were included in the average. The persistence of errors in Unit 1 relative to the errors in units nearer the goal would be expected in terms of a goal gradient effect, but hardly an increase in the cumulative average for the first six trials in a maze being encountered for the first time. Second, there was a tendency for the regular alternating pattern of the curve to shift backward toward the start of the maze from the earlier to the later trials. The curve for Trials 1 and 2 changes at Unit 6, and that for Trials 1 through 12 at Unit 4. Since the O.L. pattern of errors also alternates between Units 1 and 2 and Units 2 and 3, this may be looked at another way: as a tendency for the change in the expected direction of the alternating curve to appear closer to the start of the maze in the later stages of practice. The pictures for the I.L. and R.L. sessions are not as clear as for the O.L. session because of previous practice. The curves were distinctly bowed from the start of running, and the final characteristic alternating pattern of errors was in evidence at all stages of practice.

III. Discussion

It may be stated, to a large extent retrospectively, that the heuristic use of the similarity factor in the first experiment could not be expected to enlarge our knowledge of the relationship between interference and similarity as defined by the patterns used here because, in addition to number and serial positions of interpolated reversals, there were factors associated with task complexity, such as changes in the line of progress and asymmetrical arrangement of the entrance and goal boxes, which were not defined operationally at the outset nor varied systematically. This point becomes quite clear when the inverse relation between interference and difficulty of the I.L. task is submitted to a more elaborate test of the applicability of the similarity factor than was available to Webb (19), who obtained a similar result in 1917. Let it be assumed that the rat, on approaching choice points, always met the same field of sensory stimulation in O.L and I.L., but that, during I.L., certain choice points required different responses than during O.L. The assumption is, of course, questionable for motor activity since it takes no account of the role of kinesthesis associated with sequence of turns. Osgood's (14) three subparadigms, based on his synthesis of the verbal-learning research on the similarity factor, predict the kind and direction of transfer and interference to be expected, presumably in all cases of variation of stimuli and responses. Only the second subparadigm appears to apply here, which predicts, for the case in which stimuli are functionally identical in the second task of the transfer series and responses vary along a dimension of similarity, that there will be negative transfer and interference, both decreasing with increased similarity between the responses. It is clear from Table 6 that the relation between interference and difficulty of the interpolated task is not a simple function of the number of reversals. If, following Ballachey's results (1), Pattern B were regarded as functionally most similar to Pattern A, then interference would vary inversely with degree of similarity between O.L. and I.L. in accordance with Osgood's subparadigm. But there still remains the task of explaining why Pattern B became functionally most similar to Pattern A in terms that permit prediction since it was the most difficult interpolated task, and also why the opposite was true for Pattern C. The error curves (Fig. 1) show that Pattern B did not produce the greatest mean error until after the fifth or sixth trial, prior to which the group means were about equal. The greater difficulty of Pattern B during I.L. was not uni-

TABLE 6

Comparison of Degree of Interference, Number of Reversals, and Difficulty of the Tasks

Pattern	B	C	D	E
t ratios of interference	.41	3.92	3.05	2.69
No. of reversals	14	8	8	4
Mean error in I.L.	36.2	22.2	26.4	28.8
Mean error in R.L.	16.6	31.1	21.1	21.9

formly distributed over the reversals, but presumably was due largely to some special function associated with Unit 1, for 67 per cent of the possible errors in the first eight trials occurred here. The corresponding percentages for Patterns C, D, and E are 56, 28, and 26. To a lesser extent, the same thing occurred in Unit 12, the percentages being 26, 10, 21, and 22 for Patterns B, C, D, and E, respectively; and in Unit 14, the percentages being 29, 18, 9, and 17, respectively, for these patterns. The same thing cannot be said for any other unit in Pattern B. Similar analyses of the R.L. data showed that the blinds in Units 1, 2, and 12 were much more potent sources of interference than the other blinds, and that these units may be regarded as the focal points of patterned responses. The foregoing merely demonstrates the limitations of the transfer theory of interference when stimuli and responses are defined as they were in these complex tasks. The difficulty seems to be primarily one of keeping the stimuli and responses operationally discrete in motor learning.

The original response pattern may be explained by the following principles: (*a*) a goal gradient effect (10) for the tendency to backward elimination of errors; (*b*) either *centrifugal swing* (1, 15) or *forward-going tendency* (3) for the alternating pattern of errors reflected in relatively more errors in the even-numbered units, whether or not they were goal-pointing; both these principles seem to be reflected by the data and both express the effects of local maze structure; (*c*) goal anticipation (2, 16, 17) or *choice-point expectancy* (6) for the predominance of errors in Unit 12 and to a lesser extent in the immediately preceding units and the general uptilt in the part of the curve near the goal, excluding Unit 14. (*d*) The operation of a hypothetical principle of abstractive behavior (12), involving set formation or positioning, would seem to be necessary to account for the behavior at the start of the maze, especially the predominance of entrances to the blind in Unit 1. It would seem, moreover, that such a principle encompassed not only the general direction of the food box, but also the alternating pattern of responses. It is not essential that these principles be characterized more exactly. The data clearly seem to support the generalization that interference, rather than being tied in with the specific loci of interpolated reversals, tended to occur in units in which, during original learning, errors tended to occur more frequently where they would be expected to occur in accordance with these principles as far as they can be identified.

A few further details of the pattern analysis may be cited in justification of the above conclusion. The single alternation Pattern C was easiest during I.L., but produced most interference with relearning. Since it contained eight reversals in comparison with 14 in Pattern B and eight in Pattern D, an explanation of the result was then sought in terms of the principles of centrifugal swing or forward-going tendency. This showed that the pattern of interference, including increases in errors which were not statistically significant, increased and decreased from unit to unit in almost parallel fashion with the pattern of first-choice errors in O.L., regardless of the loci of reversals in I.L. (Table 7), and both patterns of errors can be accounted for largely in terms of these principles. The parallelism does not hold for Units 2 and 3, the area in which the curve of errors changed direction. This circumstance then seemed to call for the operation of a principle of responding that was different from any yet considered. A similar parallelism can be demonstrated for Pattern D, but it is difficult to do so for Pattern E in view of the more complex arrangement of turns. Pattern B, of course, produced facilitation, but the fact that the negative transfer produced during I.L. by this pattern was concentrated mainly in Units 1, 12, and 14, and also its functional similarity to Pattern A during R.L., would also appear to be evidence in favor of some sort of abstractive behavior.

The predominance of errors in Unit 1 during O.L. is understandable in terms of backward elimination of errors, but this principle does not account for the increase in errors in

TABLE 7

COMPARISON OF PATTERN OF O.L. ERRORS AND PATTERN OF INTERFERENCE: GROUP C

Unit	O.L.		R.L.	
	Turn	Mean Error	Turn	t ratio (Interference)
1	L	12.6	L	2.37*
2	L	5.9	**R**	4.70**
3	R	6.3	**L**	.32
4	R	4.8	R	1.04
5	L	4.0	L	.95
6	L	5.5	**R**	3.20**
7	R	3.3	**L**	.28
8	R	4.4	**L**	1.18
9	L	3.2	**R**	.47
10	L	5.1	L	1.15
11	R	3.2	R	.37
12	R	7.1	**L**	4.38**
13	L	3.6	**R**	.00
14	L	5.9	L	2.26*

Note.—Boldface indicates a reversal during I.L.

* Significant at the 5% level.

** Significant at the 1% level.

this unit over the early trials nor for the intriguing shift of the unit of maximal errors to Units 2 and 3 (Patterns D and E) during I.L. which, as already shown, cannot be attributed to the presence of reversals. The blinds in the first three units may have served to activate an anticipation or set for both the goal direction and the alternating running response, presumably a set for the correct pattern of turns, the characteristic pattern of errors being forced by local structural features of the maze. In order for centrifugal swing to produce errors, the maze yet be learned, it seems necessary to assume that the behavior at and near the start of the maze was governed by a different principle, one that was relatively independent of situational factors. In the case of Pattern A, the last two correct turns into the food box are left turns so that, in accordance with the principle of reinforcement, turning left in Unit 1 should have become easier in subsequent trials; whereas there was a greater tendency to turn right in the early trials, and this increased for at least six trials. It is as though a bidirectional gradient of reinforcement from one trial to the next began to operate early in O.L. but was offset by some other tendency that caused Blind 1 to be entered more frequently until some other adjustment had taken place. Association by contiguity does not help here if by "the last occasion" is meant either one or two left turns into the food box.

Concerning the reversal of direction of the curve of errors in Units 2, 3, 4, or 5, if the alternating pattern of correct responses had been continued regularly from trial to trial, opposed response tendencies would have been produced on alternate trials; i.e., in Trial 2 the correct turns in Units 1 and 2 in Pattern A would have been RR. It would seem to be necessary, therefore, to assume that, while the pattern of running was forced by the maze structure, it was also learned as a pattern, or "cognitively." The rat, having made two left turns into the food box on a previous run, tended on the next run to make two right turns at choice points which led it into Blinds 1 and 2 in accordance with the alternation pattern of response, but the principle of centrifugal swing which was mainly responsible for the alternating pattern of errors would have produced maximum errors in the even-numbereed blinds, beginning with Blind 2. Therefore, in order for Blind 1 to persist as a potent source of errors in accordance with the assumption that it was the focal point of operation of a different principle while the rat learned the maze, the alternating pattern of errors had to be reversed somewhere along its course. This tended to occur near the start of the maze, with the suggestion that it occurred nearer the goal in the early trials. This point needs to be tested further, however, possibly employing massed practice and finer units of measurement.

The argument, so far, seems to justify the assumption of a principle of responding in addition to backward elimination of errors to account for the errors in Unit 1 during O.L. A consideration of the state of affairs during I.L. and R.L., however, does not permit a more precise specification of the nature of such a principle other than that the responses which it would have to encompass would require that it be one of considerable lability. During I.L., Units 2 and 3 in Patterns D and E displaced Unit 1 as the maximal sources of errors, and there were similar shifts during R.L. which are not ascribable to the presence of reversals during I.L. During I.L., the occurrence of a first reversal in Unit 2 in Patterns C and D was attended by opposite effects—in the first case no change in the status of this unit as the one in which most errors were made, and in the second case the emergence of Unit 3 as the greatest source of errors. During R.L., in the case of Pattern C, Unit 1 lost its status to Unit 2 as the maximum source of errors, but in the case of Pattern D the effect that occurred in I.L. persisted through R.L.

This analysis is too descriptive to establish beyond doubt the case for a principle of abstractive behavior. Questions must be answered as to why the rat must actually enter the blind in Unit 1, rather than merely pausing, in order to get a hypothetical set functioning, and why, indeed, it did not become functional in the entrance box or first alley—but they are beyond the scope of this study.

The results of the first experiment weaken the case for the transfer theory of interference based on verbal-learning research to the extent that the transfer was not a graded function of similarity, and to the extent that determinants of interference associated with pattern nullified the influence of specific reversals. It may, of course, be possible to express patterned effects in terms of similarity. The finding in the second experiment of most interference for interpolation adjacent to O.L. is contrary to most of the findings in verbal-learning experiments which have indicated that there are other high points for interference nearer to R.L. or that interference is independent of the temporal position of the interpolated task. The present outcome could therefore be taken as supporting the somewhat outmoded perseveration theory of interference if a neurophysiological setting-in process operating in the order of days, rather than seconds, could reasonably be assumed to underlie the retention of the O.L. task. The results of Experiment III are inconclusive.

Much remains to be done to define the rela-

tionships between the principles of maze running and interference. The limiting conditions of the effects on interference of factors associated with response pattern, in comparison with the effects of reversals, need to be examined with mazes of fewer units and of a more comprehensive experimental design. All possible variations between the O.L. and I.L. tasks in congruent and adjacent units should be imposed. For example, it would be interesting to test for spread of interference at loci of reversals that were followed and preceded by true paths leading in opposite directions. Interference for mazes in which the different response patterns were produced in uncomplicated forms might be compared. In making such comparisons it would be of interest to specify the genesis of facilitation and interference in such terms as the emergence of dominant units in the production of these effects. The problem of the extent to which interference is a "cognitive" or an emotional function might be explored in terms of comparisons of the results for first-choice errors with those for other recorded performance indices. In the present study, the divergent results during I.L. and R.L. for the different indices of performance may mean that transfer and interference are mediated by different processes.

IV. Summary

A fourteen-unit, multiple-T maze was the original and relearned task for matched groups of 10 rats in three experiments in which the interpolated tasks were, respectively, (*a*) four patterns differing in number and loci of reversed choice points, (*b*) the task producing most interference in the first experiment, practiced at three temporal points, and (*c*) 5, 10, 15, or 20 trials in the same task as in *b*. Significant interference was shown by 9 of the 11 experimental groups, most markedly in the first two R.L. trials, but until at least the eighth trial. The tenth group showed insignificant interference; the eleventh, significant facilitation. The mean group interference was 23.5 per cent; the maximum, 35.5 per cent. Interference varied inversely as the difficulty of the I.L. task. It decreased with increase in temporal separation of the I.L. and O.L. tasks, and increased as the mean number of trials increased to a point about equal to the mean O.L. trials, after which it decreased. In the latter case, the changes in amount of interference were not statistically significant. The typical serial learning curve, reflecting the operation of several known principles of maze running, was established early in the O.L. series and persisted through the other series despite the interpolation of diverse patterns of reversals. Interference was not specific to the loci of reversals, but tended to occur at points in the maze where the errors in O.L. were attributable to the identified principles, particularly near the start and in the last goal-pointing blind.

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